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UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1259

Washington, D. C. ▼ October 9, 1924

STANDARD SPECIFICATIONS FOR STEEL HIGHWAY BRIDGES

Adopted by the

AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS

And approved by the

SECRETARY OF AGRICULTURE

FOR USE IN CONNECTION WITH FEDERAL-AID ROAD WORK

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INTRODUCTION.

The standard specifications for steel highway bridges set forth in this bulletin are those recommended by the subcommittee on bridges and structures of the American Association of State Highway Officials. They were presented to the association at its annual meeting at Kansas City, Mo., December 4 to 7, 1922, and were subsequently adopted by the association by letter ballot. They have since been approved by the Secretary of Agriculture for use in connection with the administration of Federal appropriations for construction of the Federal aid highway system.

The membership of the subcommittee on bridges and structures of the American Association of State Highway Officials follows:

E. F. Kelley, U. S. Bureau of Public Roads, Washington, D. C., *Chairman.*
E. E. Brandow, State Highway Department, Pennsylvania, *Secretary.*
J. H. Ames, State Highway Commission, Iowa.
C. E. Andrew, Department of Public Works, Washington.
G. F. Burch, Department of Public Works and Buildings, Illinois.
W. L. Craven, State Highway Commission, North Carolina.
L. N. Edwards, State Highway Commission, Maine.
J. T. Ellison, State Highway Department, Minnesota.
W. R. Glidden, State Highway Commission, Virginia.
C. B. McCullough, State Highway Commission, Oregon.
C. A. Mead, Board of Public Utility Commissioners, New Jersey.
S. B. Slack, State Highway Department, Georgia.
M. W. Torkelson, State Highway Commission, Wisconsin.
H. E. Warrington, Department of Public Works, California.
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DIVISION I. MATERIALS.

SECTION 1. STRUCTURAL, RIVET, AND EYEBAR STEEL.

1. General.

All structural, rivet, and eyebar steel shall conform to the requirements of the Standard Specifications for Structural Steel for Bridges, Serial Designation A7–21, of the American Society for Testing Materials, with subsequent amendments and additions thereto adopted by the society, and supplemented by the following paragraphs:

2. Character of fracture.

Test specimens of structural, rivet, or eyebar steel shall show a fracture having a silky or fine granular structure throughout with a bluish gray or dove color, and shall be entirely free from granular, black, and brilliant specks.

3. Defects in material.

Finished rolled material shall be free from cracks, flaws, injurious seams, laps, blisters, ragged and imperfect edges, and other defects. It shall have a smooth, uniform finish, and shall be straightened in the mill before shipment.

Material shall be free from loose mill scale, rust pits, or other defects affecting its strength and durability.

4. Full - sized tests.

When full-sized tests of built-up structural members and eyebars are required by the contract the contractor

shall supply testing machines of the proper type and capacity and shall provide all facilities and labor incidental to the making of tests. In all tests involving the determination of tensile and compressive strengths the ultimate strength, deformation, and other pertinent data shall be recorded.

5. Payments for full-sized tests. Any full-sized member tested to destruction shall be paid for by the purchaser at the unit contract price, less its scrap value, if the test proves satisfactory. If the test proves the member to be unsatisfactory, the members represented by it will be rejected. The expense of conducting tests shall be borne by the contractor unless otherwise provided.

SECTION 2. EYEBARS.

1. Full - sized tests. When tests of full-sized bars are required the following conditions and requirements shall supplement the general provisions of section 1 above:

2. Number and size of test bars. The number and size of the bars to be tested shall be designated by the engineer before the mill order is placed. The number shall not exceed 5 per cent of the whole number of bars ordered, with a minimum of two bars on small orders.

3. Selection of test bars. The test bars shall be of the same section as the bars to be used in the structure and of the same length if within the capacity of the testing machine. They shall be selected by the inspector from the finished bars, preferably after annealing. Test bars representing bars too long for the testing machine shall be selected from the full-length bar material after the heads on one end have been formed and shall have the second head formed upon them after being cut to the greatest length which can be tested.

4. Physical requirements. Full-sized tests of eyebars shall show a yield point of not less than 29,000 pounds per square inch, an ultimate strength of not less than 54,000 pounds per square inch, an elongation, including fracture, of not less than 10 per cent, in a length of 20 feet measured in the body of the bar. The fracture shall show a uniform silky or fine granular structure throughout.

5. Failure to meet requirements. If a bar fails to fulfill the specified requirements, two additional bars of the same size and from the same melt shall be tested. If the failure of the first bar tested is on account of the character of the fracture only, the bars represented by the test may be reannealed before the additional bars are tested.

If two of the three test bars fail to give satisfactory results, the bars of that size and melt shall be rejected.

In general, test bars shall be so selected that every melt of material entering into the various sizes of bars shall be represented by at least one test.

A failure in the head of a bar shall not be cause for rejection if the other requirements are fulfilled.

A record of the annealing charges shall be furnished the engineer showing the bars included in each charge and the treatment they received. 6. Record of annealing.

SECTION 3. STEEL FORGINGS.

Steel forgings from which pins, rollers, trunnions, or other forged parts are to be fabricated, shall conform to the requirements of the Standard Specifications for Carbon-Steel Forgings for Locomotives, Serial Designation A20–21, of the American Society for Testing Materials, with subsequent amendments and additions thereto adopted by the society. 1. General.

All forgings shall be thoroughly annealed prior to being machined to form finished parts. 2. Annealing.

SECTION 4. WROUGHT IRON.

Wrought iron shall conform to the requirements of the Standard Specifications for Refined Wrought-Iron Bars, Serial Designation A41–18, of the American Society for Testing Materials, with subsequent amendments and additions thereto adopted by the society.

SECTION 5. STEEL CASTINGS.

Steel castings shall conform to the requirements of the Standard Specifications for Steel Castings, Serial Designation A27–21, of the American Society for Testing Materials, with subsequent amendments and additions thereto adopted by the society, and supplemented by the following: 1. General.

Unless otherwise specified all castings shall be Class B, medium grade.

All steel castings shall be thoroughly annealed unless otherwise provided. 2. Annealing.

Steel castings shall be true to pattern in form and dimensions, free from pouring faults, sponginess, cracks, blowholes, and other defects in positions affecting their strength and value for the service intended. 3. Structural defects.

Blowholes appearing upon finished castings shall be so located that a straight line laid in any direction will not cut a total length of cavity greater than 1 inch in any 1 foot, nor shall any single blowhole exceed 1 inch in any dimension or have an area greater than one-half square inch. Blowholes shall not have a depth injuriously affecting the strength of the casting. Minor defects which do not impair the strength may, with the approval of the engineer, be welded by an approved process. The defects shall be removed to solid metal by chipping, drilling, or other satisfactory methods, and, after welding, the castings shall be annealed, if required by the engineer. Castings which have been welded without the engineer's permission shall be rejected.

Large castings, if required by the engineer, shall be suspended and hammered all over. No cracks, flaws, or other defects shall appear after such treatment.

No sharp unfilleted angles or corners will be allowed.

SECTION 6. GRAY-IRON CASTINGS.

1. General. Iron castings shall conform to the requirements of the Standard Specifications for Gray-Iron Castings, Serial Designation A48–18, of the American Society for Testing Materials, with subsequent amendments and additions thereto adopted by the society.

Castings shall be boldly filleted at angles and the arrises shall be sharp and perfect.

2. Structural defects. Iron castings shall be true to pattern in form and dimensions, free from pouring faults, sponginess, cracks, blowholes, and other defects in positions affecting their strength and value for the service intended.

SECTION 7. MALLEABLE CASTINGS.

1. General. Malleable castings shall conform to the requirements of the Standard Specifications for Malleable Castings, Serial Designation A47–19, of the American Society for Testing Materials, with subsequent amendments and additions thereto adopted by the society.

The castings shall be boldly filleted at angles and the arrises shall be sharp and perfect. The surfaces shall have a workmanlike finish.

2. Structural defects. Malleable castings shall be true to pattern in form and dimensions, free from pouring faults, sponginess, cracks, blowholes, and other defects in positions affecting their strength and value for the service intended.

SECTION 8. PHOSPHOR-BRONZE.

1. General. Phosphor-bronze shall conform to the requirements of the Standard Specifications for Bronze Bearing Metals for Turn-tables and Movable Railroad Bridges, Serial Designation B22–21, of the American Society for Testing Materials, with subsequent amendments and additions thereto adopted by the society.

2. Structural defects. Bronze castings shall be free from inclusions of foreign material, casting faults, injurious blowholes or other defects rendering them unsuitable for the service intended.

DIVISION II. GENERAL CONSTRUCTION.

SECTION 1. STEEL STRUCTURES.

1. Materials. All materials shall conform to the detailed requirements specified in Division I.

Except where otherwise provided, all members shall be of structural steel and rivets shall be of rivet steel.

Forgings shall be of carbon steel and shall be thoroughly annealed before machine finishing.

Castings shall be of cast steel or cast iron, but, in general, cast iron shall be used only for unimportant parts.

Phosphor-bronze may be used in expansion bearings. Class A metal shall be used for this purpose.

2. Storage of materials.

Structural material delivered at the bridge shop receiving yard shall be stored above the surface of the ground upon platforms, skids or other supports and shall be protected as far as practicable from surface deterioration by exposure to conditions producing rust. It shall be kept free from accumulations of dirt, oil, or other foreign matter.

Fabricated material stored prior to shipment shall be subject to the same conditions of storage as the unfabricated material in the shop receiving yard.

3. Straightening material.

All deformed structural material shall be properly straightened by methods which are noninjurious prior to being laid off, punched, or otherwise worked in the shop. Sharp kinks and bends shall be cause for rejection.

4. Workmanship and finish.

The workmanship and finish shall be first class and equal to the best practice in modern bridge shops. Shearing and chipping shall be neatly and accurately done and all portions of the work exposed to view shall be neatly finished.

5. Changes and substitutions.

No changes shall be made in any drawing after it has been approved except by the consent or direction of the engineer in writing.

Substitutions of sections having different dimensions than those shown on the plans shall be made only when approved in writing by the engineer.

RIVET HOLES.

6. Rivet holes.

When general reaming is not required, holes in material $\frac{3}{4}$ inch or less in thickness may be punched full size. Holes in material more than $\frac{3}{4}$ inch in thickness shall be subpunched and reamed, or drilled from the solid.

7. Punched holes.

Full-sized punched holes shall be $\frac{1}{16}$ inch larger than the nominal diameter of the rivet. The diameter of the die shall not exceed the diameter of the punch by more than $\frac{3}{32}$ inch. Holes must be clean cut, without torn or ragged edges. If any holes must be enlarged to admit the rivets, they shall be reamed.

8. Accuracy of punched holes.

The punching of holes shall be so accurately done that, after assembling the component parts of a member, a cylindrical pin $\frac{1}{8}$ inch smaller than the nominal diameter of the punched hole may be passed through at least 75 of any group of 100 contiguous holes in the same surface or in like proportion for any group of holes. If this requirement is not fulfilled the badly punched pieces shall be rejected. If any holes will not pass a pin $\frac{3}{16}$ inch smaller than the nominal diameter of the punched hole, this shall be cause for rejection.

9. Drilled holes.

Drilled holes shall be $\frac{1}{16}$ inch larger than the nominal diameter of the rivet. Burrs on the outside surfaces shall be removed with a tool producing a $\frac{1}{16}$-inch fillet around the edge of the hole.

10. Subpunched and reamed holes.

Subpunched and reamed holes shall be punched $\frac{3}{16}$ inch smaller than the nominal diameter of the rivet and shall then be reamed to a diameter $\frac{1}{16}$ inch larger than the nominal diameter of the rivet. The punch and die shall have the same relative sizes as specified for full-size punched holes. Burrs produced by reaming shall be removed with a tool producing a $\frac{1}{16}$-inch fillet around the edge of the hole.

Reaming of rivet holes shall be done with twist drills or with short taper reamers. Reamers preferably shall not be directed by hand. No oil or grease shall be used as a lubricant.

11. Accuracy of reamed and drilled holes.

Reamed or drilled holes shall be cylindrical and perpendicular to the member and their accuracy shall be the same as specified for punched holes except that, after reaming or drilling, 85 of any group of 100 contiguous holes in the same surface, or in like proportion for any group of holes, shall not show an offset greater than $\frac{1}{32}$ inch between adjacent thicknesses of metal.

12. Drifting of holes.

The drifting done during assembling shall be only such as to bring the parts into position, and not sufficient to enlarge the holes or distort the metal.

13. General reaming.

General reaming may be required, in which case a definite provision to this effect shall be included elsewhere in the contract.

When general reaming is required, all rivet holes in main members shall be subpunched and reamed or drilled from the solid. This requirement shall not apply to rivet holes in top and bottom chord lateral members, lateral hangers, truss and girder sway bracings, and to the lateral plates, connection angles, etc., connecting these members to the main members of the structure. Connection plates or other parts acting both as main member material and secondary (lateral, sway bracing, etc.) member material shall generally have subpunched and reamed holes in locations engaging similar holes in main members.

Reaming shall be done after the pieces forming a built member are assembled and firmly bolted together. No interchange of reamed parts will be permitted.

14. Field connections.

When general reaming is required, or in punched work when specifically required by the engineer, holes for field connections, except those in lateral, longitudinal, and sway bracing, shall be reamed or drilled. Riveted trusses shall be assembled in the shop, the parts adjusted to line and fit, and the holes for field connections reamed or drilled while so assembled. Holes for other field connections shall be reamed or drilled with the connecting parts assembled, or else reamed or drilled to a metal templet not less than 1 inch thick.

15. Shop assembling.

All surfaces of metal to be in contact when assembled shall be carefully painted with one coat of the paint specified for the shop coat. The paint shall be applied upon surfaces free from dirt, loose mill scale or other

foreign matter and the parts shall be assembled while the paint is plastic.

The component parts of a built member shall be assembled, drift-pinned to prevent lateral movement, and firmly bolted to draw the parts into close contact before reaming, drilling, or riveting is begun. Assembled parts shall be taken apart, if necessary, for the removal of burrs and shavings produced by the reaming operation.

The member shall be free from twists, bends, or other deformations.

Preparatory to shop-riveting full-sized punched material, the rivet holes shall be cleared for the admission of the rivets by reaming.

End connection angles, stiffener angles, etc., shall be carefully adjusted to correct locations and rigidly bolted, clamped, or otherwise firmly held in place until riveted.

16. Match-marking.

Connecting parts assembled in the shop for the purpose of reaming or drilling holes in field connections shall be match-marked, and a diagram showing such marks shall be furnished to the engineer.

17. Rivets.

The diameter of rivets indicated upon the plans shall be understood to mean their diameter before heating.

Heads of driven rivets shall be of approved shape, concentric with the shanks, true to size, full, neatly formed, free from fins and in full contact with the surface of the member.

18. Field rivets.

Field rivets, for each size and length, shall be supplied in excess of the actual number to be driven to provide for losses due to misuse, improper driving or other contingencies. Rivets shall be free from furnace scale on their shanks and from fins on the under side of the machine-formed heads.

19. Bolts and bolted connections.

Bolted connections shall not be used unless specifically authorized. Where bolted connections are permitted the bolts furnished shall be unfinished bolts (ordinary rough or machine bolts) or turned bolts, as specified or directed by the engineer.

Unfinished bolts.—Unfinished bolts shall be standard bolts with hexagonal heads and nuts. The use of "button-head" bolts will not be permitted. Bolts transmitting shear shall be threaded to such a length that not more than one thread will be within the grip of the metal. The bolts will be of lengths which will extend entirely through their nuts but not more than ¼ inch beyond them. The diameter of the bolt holes shall be $\frac{1}{16}$ inch greater than the diameter of the bolts used.

Turned bolts.—Holes for turned bolts shall be carefully reamed or drilled and the bolts turned to a driving fit by being given a finishing cut. The threads shall be entirely outside of the holes and the heads and nuts shall be hexagonal. Approved nut locks shall be used on all bolts unless permission to the contrary is secured from the engineer. When nut-locks are not used,

round washers having a thickness of ⅛ inch shall be placed under the nuts.

20. Riveting. Rivets shall be heated uniformly to a light cherry-red color and shall be driven while hot. The heating of the points of rivets more than the remainder will not be permitted. When ready for driving they shall be free from slag, scale and other adhering matter and when driven they shall completely fill the holes. Burned, burred or otherwise defective rivets, or rivets which throw off sparks when taken from the furnace or forge shall not be driven.

Loose, burned, badly formed or otherwise defective rivets shall be cut out. Caulking and recupping of rivet heads will not be allowed. In cutting out defective rivets care shall be taken not to injure the adjacent metal and, if necessary, the rivet shanks shall be removed by drilling.

Countersinking shall be neatly done and countersunk rivets shall completely fill the holes.

Shop rivets shall be driven by direct-acting riveters where practicable. The riveting machine shall retain the pressure for a short time after the upsetting is complete.

Pneumatic hammers shall be used for field riveting except when the use of other hand tools for riveting is permitted by the engineer.

21. Edge planing. Sheared edges of material more than ⅝ inch in thickness shall, when required by the engineer, be planed to a depth of not less than ⅛ inch. Reentrant cuts shall be filleted before cutting.

22. Planing of bearing surfaces. Ends of columns taking bearing upon base and cap plates shall be milled to true surfaces and correct bevels after the main section of these members and the end connection angles have been fully riveted.

Caps and base plates of columns and the sole plates of girders and trusses shall have full contact when assembled. The plates, if warped or deformed, shall be hot-straightened, planed or otherwise treated to secure an accurate, uniform contact. After being riveted in place the excess metal of countersunk rivet heads shall be chipped smooth and flush with the surrounding metal and the surfaces which are to come in contact with other metal surfaces shall be planed or milled, if necessary, to secure proper contact. Correspondingly, the surfaces of base and sole plates which are to come in contact with masonry shall be rough-finished if not free from warps or other deformations.

Surfaces of cast pedestals and shoes which are to come in contact with metal surfaces shall be planed and those which are to take bearing upon the masonry shall be rough-finished.

In planing the surfaces of expansion bearings the cut of the tool shall be in the direction of expansion.

Surfaces of bronze bearing plates intended for sliding contact, shall be carefully milled and polish-finished.

23. Abutting joints.

Abutting ends of compression members shall, after the members have been riveted, be accurately faced to secure an even bearing when assembled in the structure.

Ends of tension members at splices shall be rough-finished to secure close and neat but not contact-fitting joints.

24. End connection angles.

End connection angles of floor beams and stringers shall be flush with each other and accurately set as to position and length of member. In general, end connection angles shall not be finished unless required by the terms of the contract. However, faulty assembling and riveting may be cause for requiring them to be milled, in which case their thickness shall be reduced not to exceed $\frac{1}{16}$ inch, nor shall their rivet-bearing value be reduced below design requirements.

25. Built members.

The several pieces forming one built member shall be straight and close-fitting. Such members shall be true to detailed dimensions and free from twists, bends, open joints or other defects resulting from faulty fabrication and workmanship.

26. Lacing bars

The ends of lacing bars shall be neatly rounded unless otherwise indicated.

27. Plate girders.

Web plates.—Web plates of girders having no cover plates may be detailed with the top edge of the web flush with the backs of the flange angles. Any portion of the plate projecting beyond the angles shall be chipped flush with the backs of the angles. Web plates of girders having cover plates may be $\frac{1}{2}$ inch less in width than the distance back-to-back of flange angles.

When web plates are spliced, not more than $\frac{3}{8}$ inch clearance between ends of plates will be allowed.

Web stiffeners.—End stiffener angles of girders and stiffener angles intended as supports for concentrated loads shall be milled or ground to secure a uniform, even bearing against the flange angles. Intermediate stiffener angles shall fit sufficiently tight to exclude water after being painted.

Web splices and fillers.—Web splice plates and fillers under stiffeners shall fit within $\frac{1}{8}$ inch at each end.

28. Eyebars.

Eyebars shall be straight and true to size, and shall be free from twists, folds in the neck or head, or any other defect affecting their service strength. Heads shall be made by upsetting, rolling or forging. Welds in the body portions or in the heads of bars will not be permitted. The form of the heads may be determined by the dies in use at the works where the eyebars are to be made, if satisfactory to the engineer. The thickness of head and neck shall not overrun more than $\frac{1}{16}$ inch.

Boring.—Before boring, each eyebar shall be properly annealed and carefully straightened. Pinholes shall be located on the center line of the bar and in the centers of

the heads. The holes in the ends of bars shall be bored simultaneously and shall be so accurately located that when the bars of the same truss panels are placed in a pile the pins may be completely inserted in the pinholes without driving. All eyebars intended for the same locations in the trusses shall be interchangeable.

29. Annealing. All eyebars shall be annealed by heating uniformly to the proper temperature followed by slow and uniform cooling in the furnace. The temperature of the bars shall be under full control at all stages.

Forged pins, and other steel parts requiring their full strength, which have been partially heated shall be subsequently annealed. Slight bends in pieces of secondary importance may be made without heating the metal. Crimped web stiffeners need not be annealed.

30. Pins and rollers. Pins and rollers shall be accurately turned to detailed dimensions and shall be smooth, straight, and free from flaws. The final surface shall be produced by a finishing cut.

Forged pins.—Pins having a diameter greater than 6 inches shall be forged and annealed.

Bored pins.—Pins larger than 8 inches in diameter shall have a hole not less than 2 inches in diameter bored longitudinally through their centers. Pins showing defective interior conditions shall be rejected.

31. Boring pin holes. Pinholes shall be bored true to detailed dimensions, smooth and straight, at right angles with the axis of the member and parallel with each other unless otherwise required. A finishing cut shall always be made.

The length outside-to-outside of holes in tension members and inside-to-inside of holes in compression members shall not vary from detailed dimensions more than $\frac{1}{32}$ inch. Boring of holes in built-up members shall be done after the riveting is completed.

32. Pin clearances. The difference in diameter between the pin and the pin hole shall be not more than $\frac{1}{32}$ inch.

33. Welds. Welding of steel shall not be permitted except to remedy minor defects and then only with the approval of the engineer.

34. Screw threads. Screw threads shall make close fits in the nuts and shall be U. S. Standard, except that for diameters greater than 1½ inches, they shall be made with 6 threads to the inch.

35. Pilot and driving nuts. Two pilot nuts and two driving nuts shall be furnished for each size of pin, unless otherwise specified.

MILL AND SHOP INSPECTION.

36. Notice of rolling and fabrication. The contractor shall give ample notice to the engineer of the beginning of work at the mill and shop, so that inspection may be provided. No material shall be rolled or fabricated before the engineer has been notified where the orders have been placed.

37. Facilities for inspection.

The contractor shall furnish all facilities for the inspection of material and workmanship in the mill and shop and inspectors shall be allowed free access to the necessary parts of the premises.

38. Inspector's authority.

The inspector shall have the power to reject materials or workmanship which do not fulfill the requirements of these specifications; but in cases of dispute the contractor may appeal to the engineer, whose decision shall be final.

Inspection at the mill and shop is intended as a means of facilitating the work and avoiding errors, and it is expressly understood that it will not relieve the contractor from any responsibility in regard to imperfect material or workmanship and the necessity for replacing the same.

39. Mill orders and shipping statements.

The contractor shall furnish the engineer with as many copies of mill orders and shipping statements as the engineer may direct. The weights of the individual members shall be shown.

40. Cost of testing.

Unless otherwise provided, the contractor shall furnish, without charge, test specimens as specified herein, and all labor, testing machines, and tools necessary to prepare the specimens and to make the full-sized tests.

41. Rejections

The acceptance of any material or finished members by the inspector shall not be a bar to their subsequent rejection, if found defective. Rejected material and workmanship shall be replaced promptly or made good by the contractor.

42. Marking and shipping.

Members weighing more than 3 tons shall have the weight marked thereon. Bolts and rivets of each length and diameter and loose nuts or washers of each size, shall be packed separately. Pins, small parts, and small packages of bolts, rivets, washers, and nuts shall be shipped in boxes, crates, kegs or barrels, but the gross weight of any package shall not exceed 300 pounds. A list and description of the contained material shall be plainly marked on the outside of each shipping container.

The weight of all tools and erection material shall be kept separate.

Anchor bolts, washers, and other anchorage or grillage materials, shall be shipped to suit the requirements of the masonry construction.

Loading and unloading.—The loading, transportation, unloading and piling of structural material shall be so conducted that the metal will be kept clean and free from injury by rough handling.

ERECTION.

43. Field inspection.

All work of erection shall be subject to the inspection of the engineer who shall be given all facilities required for a thorough inspection of workmanship.

Material and workmanship not previously inspected will be inspected after its delivery to the site of the work.

44. Storage. All material shall be stored in such manner as to prevent deterioration by rust or loss of minor parts. No material shall be piled so as to rest upon the ground or in water. All material must be placed on suitable skids or platforms.

45. Preparation of bearing area. Column bases, truss and girder pedestals and shoes shall have a full and uniform bearing upon the substructure masonry. Masonry bearing plates shall not be placed upon the bridge seat areas of piers or abutments which are improperly finished, deformed, or irregular.

The shoes and pedestals of truss and girder spans, the bases of columns, and the center and end bearings of swing spans shall be rigidly and permanently located to correct alignments and elevations. Unless otherwise provided they shall be placed on a layer of canvas and red lead applied as follows:

Thoroughly swab the hot surface of the bridge seat bearing area with red-lead paint and place upon it three layers of 12 to 14 ounce duck, each layer being thoroughly swabbed on its top surface with red-lead paint. Place the superstructure shoes or pedestals in position while the paint is plastic.

46. Handling members. The field assembling of the component parts of a structure shall involve the use of methods and appliances not likely to produce injury by twisting, bending, or otherwise deforming the metal. No member slightly bent or twisted shall be put in place until its defects are corrected, and members seriously damaged in handling shall be rejected.

47. Alignment. Before beginning the field riveting the structure shall be adjusted to correct grade and alignment and the elevations of panel points (ends of floor beams) properly regulated. For truss spans a slight excess camber will be permitted while the bottom chords are being riveted, but the correct camber and relative elevations of panel points shall be secured before riveting the top-chord joints, top lateral system, and sway bracing.

48. Straightening bent material. The straightening of bent edges of plates, angles, and other shapes shall be done by methods not likely to produce fracture or other injury. The metal shall not be heated unless permitted by the engineer, in which case the heating shall not be to a higher temperature than that producing a dark cherry red color. After heating, the metal shall be cooled as slowly as possible.

Following the completion of the straightening of a bend or buckle the surface of the metal shall be carefully inspected for evidence of incipient or other fractures.

49. Assembling and riveting. All field connections and splices shall be securely drift-pinned and bolted before riveting. Important connections in trusses, girders, floor system, etc., shall have at least 50 per cent of the holes filled. An ample number of driftpins shall be used to prevent slipping at joints and splices.

The results obtained in the field assembling and riveting of the members of a structure shall conform to the requirements for shop assembling and riveting. Field-driven rivets shall be inspected and accepted before being painted.

Field riveting shall be done before the falsework is removed, unless special permission to the contrary is given by the engineer.

Railings shall not be riveted until the falsework has been removed.

50. Adjustment of pin nuts.

All nuts on pins shall be thoroughly tightened and the pins so located in the holes that the members shall take full and even bearing upon them.

51. Setting anchorage bolts.

Anchor bolt holes shall be drilled in correct locations perpendicularly to the plane of the bridge seat, and the anchor bolts shall be set in Portland cement mortar therein. The mortar shall consist of one part cement to one part clean, fine-grained sand mixed sufficiently wet to flow freely.

Anchor bolts shall first be dropped into the dry holes to assure their proper fit after setting. They shall then be set as follows: Fill the hole about two-thirds full of mortar and by a uniform, even pressure or by light blows with a hammer (flogging and ramming will not be permitted) force the bolt down until the mortar rises to the top of the hole and the anchor bolt nut rests firmly against the metal shoe or pedestal. Remove all excess mortar which may have flushed out of the hole, to permit proper field painting of the metal surfaces.

The location of the anchor bolts in relation to the slotted holes in expansion shoes shall be varied with the prevailing temperature. The nuts on anchor bolts at the expansion ends of spans shall permit the free movement of the span.

Anchor bolts which are to be set in the masonry prior to the erection of the superstructure shall be carefully set to proper location and elevation with templets or by other suitable means.

MEASUREMENTS AND PAYMENTS.

52. Basis of payment.

The con ract price for fabrication and erection of structural steel shall include all labor, material, transportation and painting necessary for the proper completion of the work.

Payment will be made on a pound-price or a lump-sum basis, as required by the terms of the contract. For the purpose of payment, such minor items as bearing plates, pedestals, etc., shall, unless otherwise provided, be considered as structural steel even though made of other materials.

Payment for all material used in full-sized tests shall be made on a pound-price basis for pound-price contracts and, unless otherwise provided, on a basis of actual cost plus 10 per cent for lump-sum contracts. The scrap

value of all material tested to destruction shall be allowed as a credit upon such payments.

53. Weight paid for.

The payment for pound-price contracts shall be based on the weight of metal in the fabricated structure, including field rivets shipped. The weight of erection bolts, field paint, and all boxes, crates, or other containers used for packing, together with sills, struts, and rods used for supporting members during transportation, shall be excluded.

Weights paid for shall be shop-scale weights unless otherwise provided. If specified in the contract or permitted by the engineer, computed weights as hereinafter provided may be made the basis of payment.

54. Variation in weight.

If the weight of any member is more than 2 per cent less than the computed weight, it may be cause for rejection. This applies to both pound-price and lump-sum contracts.

If the total scale weight of any structure exceeds the computed weight by more than 2 per cent, the weight in excess of 2 per cent above the computed weight shall not be paid for.

55. Weighing of members.

Finished work shall be weighed in the presence of the inspector, if practicable. The contractor shall supply satisfactory scales and shall perform all work involved in handling and weighing the various parts.

56. Computed weight.

The weight of steel shall be assumed at 490 pounds per cubic foot. The weight of cast iron shall be assumed at 450 pounds per cubic foot.

The weights of rolled shapes, and of plates up to and including 36 inches in width, shall be computed on the basis of their nominal weights and dimensions, as shown on the approved shop drawings, deducting for copes, cuts, and open holes.

The weights of plates wider than 36 inches shall be computed on the basis of their dimensions, as shown on the approved shop drawings, deducting for cuts and open holes. To this shall be added one-half of the allowed percentages of overrun in weight given in the Standard Specifications for Structural Steel for Bridges, Serial Designation A7–21, of the American Society for Testing Materials.

The weight of heads of shop-driven rivets shall be included in the computed weight, assuming the weights to be as follows:

Diameter of rivet.	Weight for 100 heads.
½ inch	pounds 4. 0
⅝ inch	do 7. 5
¾ inch	do 12. 5
⅞ inch	do 18. 5
1 inch	do 27. 0

The weight of castings shall be computed from the dimensions shown on the approved shop drawings, with an addition of 10 per cent for fillets and overrun.

To the total computed weight of metal may be added an allowance of 0.4 of 1 per cent for shop paint.

SECTION 2. PAINTING STEEL STRUCTURES.

1. General conditions.

The painting of metal structures shall include, unless otherwise provided in the contract, the proper preparation of the metal surfaces, the application, protection and drying of the paint coatings, the protection of pedestrian, vehicular or other traffic upon or underneath the bridge structure, the protection of all portions of the structure (superstructure and substructure) against disfigurement by spatters, splashes and smirches of paint or of paint materials, and the supplying of all tools, tackle, scaffolding, labor, workmanship and materials necessary for the entire work.

APPLICATION OF PAINT.

2. Number of coats.

All new structural steel work shall, unless otherwise especially provided upon the plans or in the contract, be painted three coats of paint. The first coat is to be applied immediately after the shop fabrication is complete except that all surfaces coming into contact are to be painted before being assembled. The second and third coats are to be applied after all erection is complete, except that immediately following the field-riveting of the members, the heads of field rivets, and all abrasions of the shop coat due to handling at the shop, shipment, erection, etc., and all field erection marks shall be thoroughly covered with one coat of shop paint and permitted to become thoroughly dry before the first field coat is applied.

3. Colors of coats.

The color of each succeeding coat shall be sufficiently different from that previously applied to permit the discovery of an incomplete application of the paint coat. The colors of the coats shall be determined by the engineer.

4. Weather conditions.

Paint shall be applied only when the air temperature is at or above 40° F. It shall not be applied upon damp surfaces or upon metal containing frost, nor shall it be applied when the air is misty, or otherwise, in the opinion of the engineer, unsatisfactory for the work.

Material painted under cover in damp or cold weather shall remain under cover until dry or until weather conditions permit its exposure in the open. Painting in open yards or upon erected structures shall not be done when the metal has absorbed sufficient heat to cause the paint to blister and produce a porous paint film.

5. Application.

No wide, flat brushes shall be used. All brushes shall be either round or oval in shape.

The paint when applied shall be so manipulated under the brush as to produce a uniform, even coating in close contact with the metal or with previously applied paint. In general, the primary movement of the brush shall describe a series of small circles to thoroughly fill all irregularities in the surface, after which the coating shall be smoothed and thinned by a series of parallel strokes.

To secure a maximum thickness of paint film upon rivet heads, and edges of plates, angles or other rolled shapes these areas shall be "striped" in advance of the general painting, and shortly afterward shall be given a second or "wash" coat when the general coat is applied. The paint shall be well worked into all joints and open spaces.

Paint shall be thoroughly stirred preferably by means of mechanical mixers before being removed from the containers, and to keep the pigments in suspension shall be kept stirred while being applied.

All painting must be done in a neat and workmanlike manner.

On all surfaces which are inaccessible for paint brushes, the paint shall be applied with sheepskin daubers specially constructed for the purpose.

6. Removal of improper paint. All metal coated with impure or unauthorized paint shall be thoroughly cleaned and repainted to the satisfaction of the engineer, at the expense of the contractor.

7. Thinning. If it is necessary in cool weather to thin the paint in order that it shall spread more freely, this shall be done only by heating in hot water or on steam radiators.

SHOP PAINTING.

8. Shop cleaning. All surfaces of metal to be painted shall be thoroughly cleaned of rust, loose mill scale, dirt, oil or grease, and all other foreign substances. The removal of rust, scale, and dirt shall generally be done by the use of metal brushes, scrapers, chisels, hammers or other effective means. Oil and grease may be removed by the use of gasoline or benzine. Bristle or wood-fiber brushes shall be used for removing loose dust.

9. Shop painting. In shop-riveted work all surfaces coming into contact when shop-assembled shall each be painted a good shop coat thoroughly and evenly applied before assembling. These pieces may be assembled while the paint is still wet.

When all fabrication work is complete and has been accepted as such, all surfaces not painted before assembling shall be painted a good shop coat. Shipping pieces shall not be loaded for shipment until thoroughly dry. No painting shall be done after loading material on cars.

10. Erection marks. Erection marks for the field identification of members shall be painted upon previously painted surfaces.

11. Machine finished surfaces. With the exception of abutting chord and column splices, column and truss shoe bases, machine-finished surfaces shall be coated as soon as practicable after being accepted, with a hot mixture of white lead and tallow before removal from the shop. Surfaces of iron and steel castings milled for the purpose of removing scales, scabs, fins, blisters or other surface deformations shall generally be given the shop coat of paint.

The composition used for coating machine-finished surfaces shall be mixed in the following proportions: 4 pounds pure tallow, 2 pounds pure white lead, and 1 quart pure linseed oil.

FIELD PAINTING.

When the erection work is complete, including all riveting, straightening of bent metal, etc., all adhering rust, scale, dirt, grease or other foreign matter shall be removed as specified under Shop Cleaning. 12. Field cleaning.

As soon as the field cleaning is done to the satisfaction of the engineer the heads of field rivets and bolts and any surfaces from which the shop coat of paint has been worn off or has become otherwise defective and all shipping and erection marks shall be thoroughly covered with one coat of the same paint as used in the shop and permitted to become thoroughly dry before the first field coat is applied. 13. Field painting.

When the paint applied for "touching up" rivet heads and abraded surfaces has become thoroughly dry the first and second field coats may be applied. In no case shall a succeeding coat be applied until the previous coat has dried throughout the full thickness of the paint film.

All small cracks and cavities which have not been sealed in a watertight manner by the first field coat shall be filled with a pasty mixture of red lead and linseed oil before the second field coat is applied.

MAINTENANCE PAINTING.

Unless otherwise provided, maintenance painting shall consist of the removal of the rust, scale, dead paint, dirt, grease or other foreign matter from the metal parts or portions of existing bridge structures and the application of paint thereto. 14. Scope of work.

All metal surfaces not in close contact with other metal surfaces or with wooden floor or truss members, concrete, stone masonry, etc. shall be considered as exposed to deterioration by rusting and shall be thoroughly cleaned and painted the number of coats indicated in and made a part of the contract.

Unless otherwise provided, metal after being cleaned to the satisfaction of the engineer shall be painted at least two coats of paint. 15. Number of coats.

The requirements and methods of procedure for maintenance cleaning and painting shall be the same as specified for shop and field painting. 16. Cleaning and painting.

Whenever roadway or sidewalk planking is laid too closely in contact with the metal to permit free access for proper cleaning and painting, the planks shall either be removed or cut to provide at least a 1-inch clearance for that purpose. The removal or the cutting of planks shall be done as directed by the engineer. All planks removed shall be satisfactorily replaced and if broken or otherwise injured to an extent rendering them unfit for use they shall be renewed at the expense of the contractor.

DIVISION III. DESIGN.

SECTION 1. GENERAL FEATURES.

1. Width of roadway and sidewalk.

The width of roadway shall be the clear width measured at right angles to the longitudinal center line of the bridge between the tops of curbs or guard timbers, if these exist; otherwise it shall be the clear width inside-to-inside of the handrails or other fencelike protections paralleling the sides of the structure.

Upon structures having a sidewalk, the clear width of sidewalk shall be measured at right angles to the curb or guard timber and from the face thereof to the extreme inside portion of the handrail. For structures having trusses, girders, or parapet walls adjacent to the curbs the width of sidewalk shall be measured from their extreme outside portions to the inside of the handrail.

2. Curbs.

The width of curbs shall be not less than 6 inches and preferably shall be not less than 9 inches. Their height shall be not less than 9 inches.

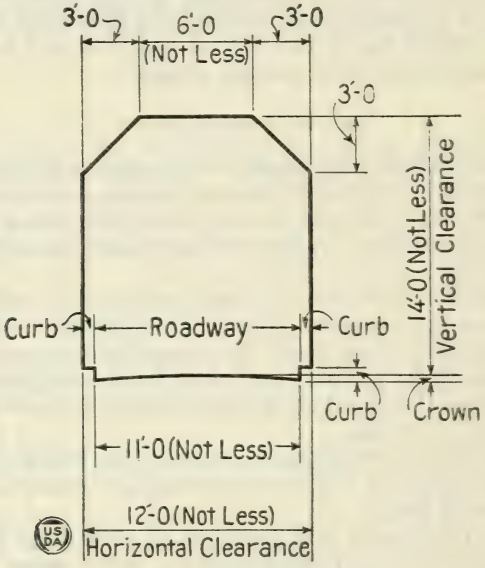

FIG. 1.—Clearance diagram for one-way highway traffic

3. Clearances.

The clearance width shall be the clear width available, and the clearance height shall be the clear height available, for the passage of vehicular traffic, as shown on the clearance diagrams.

Unless otherwise provided the several parts of the structure shall be constructed to secure the following limiting dimensions or clearances for traffic.

Bridges constructed for the use of one-way highway traffic shall have a roadway clearance not less than that shown in Figure 1. The roadway clearance for the use

of two-way traffic shall be not less than that shown in Figure 2. The roadway width shall be increased at least 9 feet for each additional line of traffic.

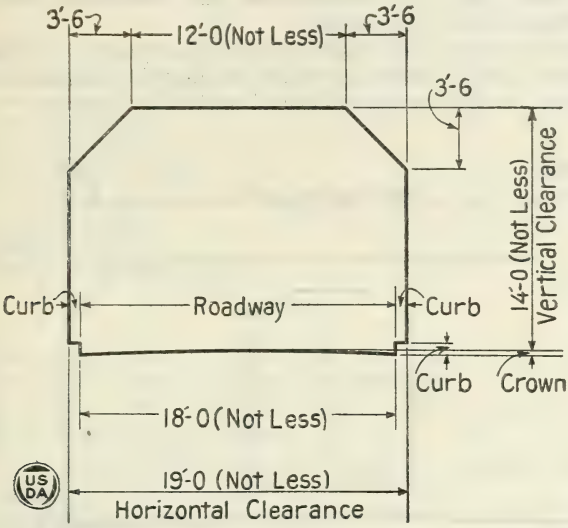

FIG. 2.—Clearance diagram for two-way highway traffic

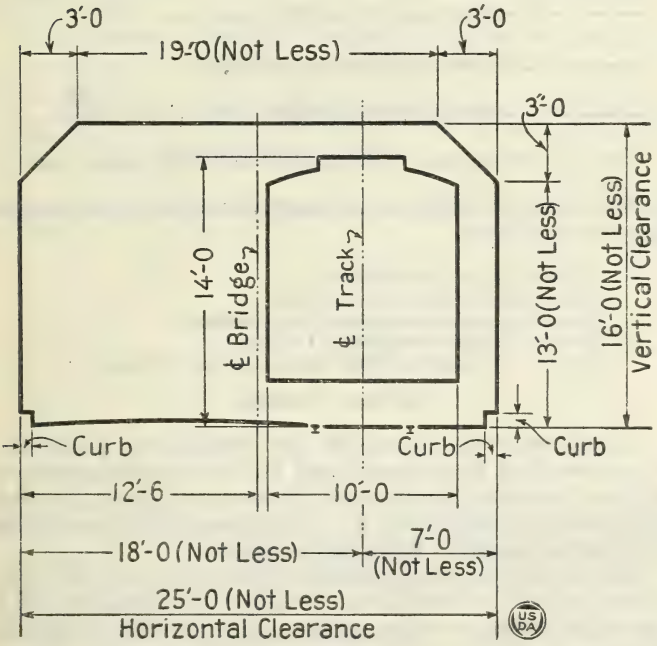

FIG. 3.—Clearance diagram for a single track railway and one-way highway traffic

Bridges constructed for the combined use of highway and electric railway traffic shall have roadway clearances not less than those shown in Figures 3 and 4.

In all cases involving curved tracks the lateral clearances shall be increased an amount corresponding to that required to maintain the standard clearances. When the outer rail is superelevated the clearances shall be correspondingly increased.

4. Spacing of trusses and girders.

Main trusses and girders shall be spaced a sufficient distance apart center-to-center, to be secure against overturning by the assumed lateral and other forces.

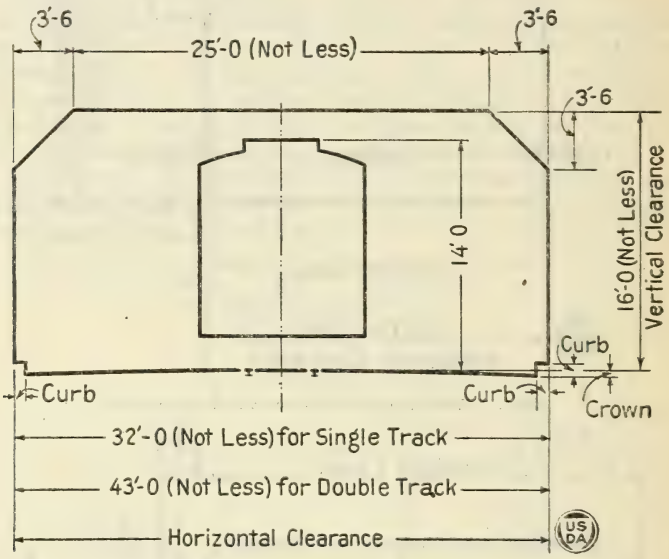

FIG. 4.—Clearance diagram for electric railway and two-way highway traffic

5. Type of bridge.

The type of bridge to be used for various span lengths may be as follows:

Rolled beams up to 40 feet.
Plate girders from 30 to 100 feet.
Low riveted trusses from 45 to 100 feet.
Riveted trusses from 90 to 150 feet.
Riveted or pin-connected trusses above 150 feet.

SECTION 2. LOADS.

Unless otherwise provided the component parts of a structure shall be proportioned for the stresses produced by the following loads with the assumed load distribution described in Section 4. The stresses due to each shall be shown separately upon stress sheets.

1. Dead load.

The dead load shall consist of the weight of the structure complete, including the weight of the roadway floor, conduits, cables, or other public utility services supported thereon.

The following weights are to be used in computing the dead load:

Substance.	Weight per cubic foot, pounds.
Steel	490
Iron, cast	450
Bronze	524
Timber (treated or untreated)	60
Concrete	144
Loose sand and earth	100
Rammed sand or gravel	120
Macadam or gravel rolled	140
Cinder filling	60
Asphalt wearing surface	150
Granite block paving	160
Vitrified brick paving	150
Granolithic pavement	150

LIVE LOAD.

2. General. Steel bridges shall be designed for either uniform or concentrated loads as hereinafter specified.

3. Traffic classification. For the purposes of design, bridges will be classified, on the basis of traffic, as follows:

Class A—Heavy-traffic bridges on primary or secondary roads.
Class B—Light-traffic bridges.
Class C—Bridges carrying a highway traffic of exceptionally heavy load units.
Class D—Bridges carrying electric railway lines, in addition to highway traffic.

4. Loading classification. For purposes of design, loadings will be divided into four classes, as follows:

Class 1–15, Class 1–20, Class 2–15, Class 2–20 } These loading classifications indicate the number and weight of trucks in tons, on which the loading specification is based.

5. Selection of loads. Loadings for the different classes of bridges shall be as follows:

Class of bridge.	Class of loading.	
	Roadway width less than 18 feet.	Roadway width 18 feet or more.
A		2–15
B	1–15	1–15
C	1–20	2–20

Class D bridges shall be designed for the specified highway live loads, of the proper class, on any portion of the roadway; or the electric railway live loads on the car tracks and the highway live loads on the remaining portion of the roadway.

6. Concentrated loads. Concentrated highway loads shall consist of typical trucks having total loaded weights of 15 tons or 20 tons, distributed as shown in Figure 5. The width of each rear truck tire shall be assumed as 1 inch per ton of gross weight of truck and load.

Upon bridges constructed for the combined use of highway and electric railway traffic the concentrated electric railway loads, unless otherwise provided, shall be one of the following two classes, viz:

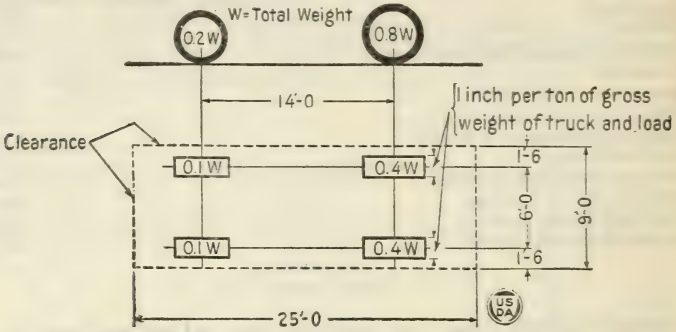

FIG. 5.—Diagram showing distribution of typical truck load

1. A train on each track composed of two double-truck cars coupled together. Each car shall be assumed to weigh, when loaded, 60 tons. The length of each car over bumpers shall be taken as 54 feet with axle loads and spacing as shown in Figure 6.

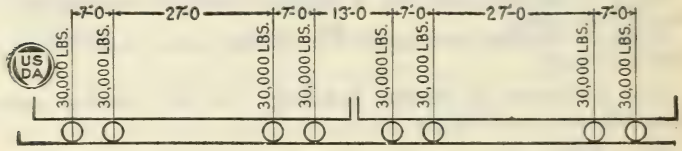

FIG. 6.—Distribution of axle loads of two 60-ton cars

2. A train on each track composed of two double-truck freight cars coupled together. Each car shall be assumed to weigh, when loaded, 100 tons. The length of each car over bumpers shall be taken as 45 feet with axle loads and spacing as shown in Figure 7.

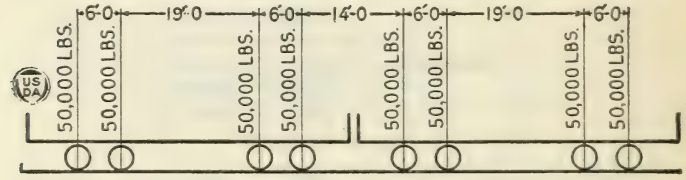

FIG. 7.—Distribution of axle loads of two 100-ton freight cars

The width of car bodies over side plates shall be taken as 10 feet and their height from top of rail to top of roof as 14 feet. The gauge of the trucks shall be taken as 4 feet 8½ inches.

7. Loadings for girders and trusses.

Girders and truss members, except as noted below, shall be designed for the following uniform loads, expressed in pounds per square foot of roadway width between curbs:

Loaded length.	Load.[1]		
	Class 1–15	Class 1–20. Class 2–15.	Class 2–20.
	Pounds.	*Pounds.*	*Pounds.*
50 feet	100	130	180
100 feet	80	90	120
200 feet and over	60	70	90

[1] Proportionate loads shall be used for intermediate lengths.

The lengths given are to be considered as loaded lengths and the uniform load used shall correspond to the length of that portion of the span which, when fully loaded, will produce maximum stress in the member under consideration.

When the loaded length is less than 50 feet, girders and truss members shall be designed for the floor loads hereinafter specified. The trucks shall be so placed as to produce the most severe stresses, but trucks in tandem need not be considered. When two lines of traffic are to be considered the trucks shall be assumed to be running in the same direction.

8. Sidewalk loading.

Sidewalk live loads shall be uniform loads of 80 pounds per square foot for loaded lengths of 50 feet or less, and 60 pounds per square foot per loaded lenths of 100 feet or more. For intermediate lengths proportionate loads shall be used. All stringers and brackets of sidewalks shall be designed for not less than 80 pounds per square foot.

9. Floor loads.

Stringers, floor beams, and floor beam hangers shall be designed for the following loads. Furthermore, girders, trusses, and truss members in which the maximum live-load stresses result from loaded lengths of less than 50 feet shall be so designed:

Class 1–15.—One 15-ton truck, or 100 pounds per square foot of roadway, whichever produces the greater stress.

Class 1–20.—One 20-ton truck.

Class 2–15.—Two 15-ton trucks.

Class 2–20.—Two 20-ton trucks.

In bridges involving three or more lines of traffic the floorbeams and floorbeam hangers shall be designed for two trucks assumed to be located in the most unfavorable position, together with a uniform live load of 100 pounds per square foot on the width of roadway not occupied by the trucks.

10. Impact.

All live loads, except those due to centrifugal, tractive, and wind forces, shall be increased to their static equivalents by a proper allowance for dynamic, vibratory, and impact effects. The amount of this allowance or

increment is expressed as a fraction of the live load or live-load stress and is determined by the following formulas.

For highway loads, $I=\frac{L+250}{10L+500}$

For electric railway loads, $I=\frac{L+900}{12L+1200}$

where

I=impact fraction.

L=loaded length in feet producing the maximum static stress in the member considered.

11. Longitudinal force. Upon bridges carrying electric railway traffic, the forces due to traction and momentum shall be considered as longitudinal forces having a magnitude equal in amount to 20 per cent of the moving railway load on one track only. Provision shall be made in the design of floor members, girders, trusses, trestle towers, etc., for these forces applied at the elevation of the tops of rails.

12. Lateral force. The force due to wind and lateral vibrations shall be taken as horizontal and shall be treated as a uniformly moving load acting only on the lateral and sway bracing. This lateral force shall be taken at 30 pounds per square foot on one and one-half times the side area of all trusses or girders plus the area of the railings and the vertical projection of the floor. In the case of truss spans it shall be considered as divided between the loaded and the unloaded chords in the proportion of two-thirds to the former and one-third to the latter. In addition to the foregoing a moving load of 150 pounds per linear foot shall be considered as acting in the plane of the bridge floor on highway bridges and 300 pounds per linear foot upon bridges for combined highway and electric railway service. However, in the case of structures having a reinforced concrete floor slab engaging the flanges of the steel floor members this additional loaded chord load need not be considered.

The transverse bracing of trestle towers and bents shall be proportioned to resist the lateral forces of the superimposed spans acting at the tops of the columns together with a pressure of 30 pounds per square foot acting against an area equal to one and one-half times the horizontally projected side areas of the columns, struts, and bracing.

The longitudinal bracing of trestle towers shall be proportioned to resist not less than 0.7 of the transverse lateral forces above described in addition to the tractive force due to electric railway traffic, when the latter exists.

13. Centrifugal force. Bridges carrying electric railway traffic on a curve shall be designed to resist a lateral force equal to 10 per cent of the moving railway load, without impact allowance. This load shall be assumed to act 4 feet above the rail.

In all statically determinate structures provision shall be made for expansion due to an extreme variation of 160° F. with a normal temperature of 60° and a range from −40° to +120°. In all statically indeterminate structures the temperature stresses resulting from the foregoing variation shall be provided for in the design. 14. Thermal forces.

SECTION 3. UNIT STRESSES.

Unless otherwise provided the several parts of a structure shall be so proportioned that the unit stresses will not exceed the following, except as provided for Structural Steel Design under Combined Stresses, Secondary Stresses and Allowance for Overload. Unless otherwise noted, all unit stresses are given in pounds per square inch. 1. General.

STEEL STRUCTURES.

2. Structural grade and rivet steel.

Tension.	
Axial tension, structural members, net section	16,000
Rivets in tension, where permitted, 50 per cent of single shear values.	
Bolts, area at root of thread	10,000
Axial compression.	
Axial compression, gross section, but not to exceed 13500 L=length of member, in inches, r=least radius of gyration, in inches.	15000−50L/r
Bending on extreme fiber.	
Rolled shapes, built sections and girders, net section	16,000
Pins	24,000
Shear.	
Girder webs, gross section	10,000
Pins and shop-driven rivets	12,000
Power-driven field rivets and turned bolts	10,000
Hand-driven rivets and unfinished bolts	7,500
Bearing.	
Pins, steel parts in contact and shop-driven rivets	24,000
Power-driven field rivets and turned bolts	20,000
Hand-driven rivets and unfinished bolts	15,000
Expansion rollers, pounds per linear inch where d=diameter of roller in inches	600d

Countersunk rivets.

In metal ⅜ inch thick and over, half the depth of countersink shall be omitted in calculating bearing area.

In metal less than ⅜ inch thick, countersunk rivets shall not be assumed to carry stress.

Diagonal tension.	
In webs of girders and rolled beams, at sections where maximum shear and bending occur simultaneously	16,000

3 Other metals.

Axial tension.	
Wrought iron	12,000
Bending on extreme fiber.	
Cast steel	12,000
Cast iron	3,000
Shear.	
Cast steel	10,000
Cast iron	3,000
Bearing.	
Cast steel	14,000
Cast iron	10,000
Bronze sliding expansion bearings	3,000

4. Bearing on bridge seats.

Bearing on concrete masonry, limestone masonry, and better	500

SECTION 4. DISTRIBUTION OF LOADS.

DISTRIBUTION OF TRUCK WHEEL LOADS TO STRINGERS AND FLOOR BEAMS.

1. Shear.

In calculating end shears and end reactions of stringers and floor beams, no lateral or longitudinal distribution of wheel loads shall be assumed.

2. Bending moment in stringers.

In determining bending moments in stringers, each wheel load shall be assumed as concentrated at a point.

When the floor system is designed for one truck, each interior stringer shall be proportioned to support that part of one rear wheel load, or those parts of one front wheel load and one rear wheel load, represented by a fraction whose numerator is the stringer spacing in feet and whose denominator is:

4 feet for plank floors.
5 feet for strip floors 4 inches or more in thickness and for wood blocks on a 4-inch plank subfloor.
6 feet for reinforced concrete floors.

When the floor system is designed for two trucks, each interior stringer shall be proportioned to support that part of one rear wheel load, or those parts of one front wheel load and one rear wheel load, represented by a fraction whose numerator is the stringer spacing in feet and whose denominator is:

3½ feet for plank floors.
4 feet for strip floors 4 inches or more in thickness and for wood blocks on 4-inch plank subfloor.
4½ feet for reinforced concrete floors.

The live load supported by the outside stringers shall be the reaction of the truck wheels in the most unfavorable position, assuming the flooring to act as a simple beam, but this live load shall in no case be less than would be required for interior stringers under the above requirements.

The above distribution rules govern only when the stringer spacing is not greater than the denominator which applies to the particular case under consideration. When the stringer spacing is greater than this distance the stringer loads shall be determined by the reactions of the truck wheels placed in the most unfavorable position, assuming the flooring between stringers to act as simple beams.

The combined load capacity of the stringers in a panel shall be not less than the total live and dead load in the panel.

3. Bending moment in floor beams.

In determining bending moments in floor beams, each wheel load shall be assumed as concentrated at a point.

When stringers are omitted and the floor is supported directly on the floor beams, the latter shall be proportioned to carry that fraction of one axle load, when the floor system is designed for one truck, or of two axle loads, when the floor system is designed for two trucks, whose numerator is the floor beam spacing in feet and whose denominator is:

4 feet for plank floors.
5 feet for strip floors 4 inches or more in thickness and for wood blocks on 4-inch plank subfloor.
6 feet for reinforced concrete floors.

When the spacing of floor beams exceeds the denominator given but is less than the axle spacing (14 feet, 0 inches) each beam shall be proportioned to carry the full axle load or loads.

When the floor beam spacing exceeds the spacing of axles the load supported on each floor beam shall be the maximum reaction due to the axle loads, assuming the flooring between floor beams to act as a simple beam.

4. Distribution of electric railway wheel loads.

Electric railway wheel loads may be assumed to be uniformly distributed longitudinally over a length of 3 feet. In the case of ballasted floors, a lateral distribution of 10 feet for an axle load may be assumed.

SECTION 5. STRUCTURAL STEEL DESIGN.

1. Dimensions for stress calculation.

Effective span.—For the calculation of stresses, span lengths shall be assumed as follows:

Beams and girders, distance between centers of bearings.
Trusses, distance between centers of end pins or of bearings.
Floor beams, distance between centers of trusses or girders.
Stringers, distance between centers of floor beams.

Effective depth.—For the calculation of stresses, effective depths shall be assumed as follows:

Riveted trusses, distance between centers of gravity of the chords.
Pin-connected trusses, distance between centers of chord pins.
Plate girders, distance between centers of gravity of the flanges, but not to exceed the distance back to back of flange angles.

2. Reversal of stress.

Members subject to reversal of stress during the passage of live load shall be proportioned as follows: Determine the tensile and the compressive stresses and increase each by 50 per cent of the smaller; then proportion the member so that it will be capable of resisting each increased stress. The connections shall be proportioned for the sum of the original stresses.

No pin-connected member shall be subjected to reversal of stress.

When the live load and dead load stresses are of opposite sign, only 70 per cent of the dead load stress shall be considered as effective in counteracting the live load stress.

3. Combined stresses.

Axial and bending.—Members subject to both axial and bending stresses shall be proportioned so that the combined fiber stresses will not exceed the allowable axial stress. Members continuous over panel points shall be proportioned for the live and dead load bending moments computed for a simple beam having a span equal to one panel length.

Stresses due to lateral and longitudinal forces and temperature.—In proportioning the various parts of the structure, provision shall be made for the following stress combinations:

Group A: Dead load; live load; impact; centrifugal force.
Group B: Lateral force; longitudinal force; temperature.

Members subject to the stresses of Group A in combination with the stresses of Group B, either direct or flexural or both, shall be designed for any of the following combinations, at unit stresses 25 per cent greater than those specified, but the resulting sections shall be not less than would be required if the stresses of Group A were considered alone.

1. The combined stresses of Group B in combination with dead load only.
2. The combined stresses of Group A in combination with 50 per cent of the combined stresses of Group B.
3. The combined stresses of Group A in combination with temperature only.

4. Secondary stresses.

Members and their details shall be proportioned to reduce secondary stresses to a minimum. In simple trusses without subdivided panels the secondary stresses due to deformation in any member whose width measured in the plane of flexure is less than one-tenth of its length need not be considered. When this ratio is exceeded, or where subdivided panels are used, the secondary stresses shall be computed.

In members designed for secondary stresses in combination with other stresses the specified allowable unit stresses may be increased 30 per cent, but the sections shall be not less than required for primary stresses.

5. Allowance for overload.

For the calculation of stress reversal or counterstresses, the specified live loads, either uniform or concentrated, shall be increased 100 per cent and for this loading condition the specified unit stresses shall be increased not more than 50 per cent. The resulting sections shall be not less than would have been required had the allowance for overload not been considered.

6. Compression flanges of beams and girders.

The gross area of the compression flanges of beams and plate girders shall be not less than the gross area of the tension flanges.

The laterally unsupported length of the compression flanges of beams and girders shall not exceed 40 times the flange width. When the unsupported length of flange exceeds 12 times the flange width, the compressive stress in pounds per square inch shall not exceed

$$19{,}000 - 250\,\frac{L}{b}.$$ (Maximum value, 16,000 pounds.)

where

L = length, in inches, of unsupported flange, between lateral connections or knee braces.

b = flange width in inches.

7. Proportioning rolled beams.

Rolled beams shall be proportioned by the moments of inertia of their sections. Proper allowance shall be made for any reduction in strength due to rivet holes in the tension flange or to any reduction in allowable stress due to the length of unsupported compression flange.

8. Limiting lengths of members.

Compression members.—The ratio of unsupported length to the least radius of gyration shall not exceed 120 for main compression and stiffening members nor 140 for laterals and sway bracing. In proportioning the top chords of low trusses the unsupported length shall be assumed as the length between the rigid verticals.

Tension members.—For main riveted tension members the ratio of length to least radius of gyration shall not exceed 200.

9. Effective bearing area.

The effective bearing area of a pin, bolt, or rivet shall be its nominal diameter multiplied by the thickness of the metal on which it bears.

RIVETS.

10. Effective diameter of rivets.

In proportioning rivets, the nominal diameter of the rivet shall be used.

11. Size of rivets.

Rivets shall be of the size specified but generally shall be ¾ inch or ⅞ inch in diameter. Five-eighth-inch rivets shall not be used in members carrying calculated stress except in 2½-inch legs of angles and in flanges of 6-inch and 7-inch beam and channels.

The diameter of rivets in angles carrying calculated stress shall not exceed one-fourth of the width of the leg in which they are driven. In angles whose size is not so determined ⅝-inch rivets may be used in 2-inch legs, ¾-inch rivets in 2½-inch legs and ⅞-inch rivets in 3-inch legs.

In no case, except in handrails, shall structural shapes be used which do not admit the use of ⅝-inch rivets.

12. Pitch of rivets.

The minimum allowable distance between centers of rivets shall be three times the diameter of the rivet but preferably shall be not less than the following:

For ⅞-inch rivets, 3 inches.
For ¾-inch rivets, 2½ inches.
For ⅝-inch rivets, 2¼ inches.

The maximum allowable pitch in the line of stress shall not exceed 6 inches or 16 times the thickness of the thinnest outside plate or angle connected, except in angles having two gauge lines with rivets staggered, where the pitch in each line may be twice the above with a maximum of 10 inches.

In webs of members composed of two or more plates in contact the rivets shall be spaced not more than 10 inches between centers in gauge and pitch, provided such rivets serve no other purpose than to hold the plates in close contact. Tension members composed of two angles in contact shall be stitch riveted, using a pitch not greater than 12 inches.

13. Pitch in ends of compression members.

In the ends of built compression members the pitch of rivets connecting the component parts of the member shall not exceed four times the diameter of the rivet for a length equal to one and one-half times the maximum width of member. Beyond this point the rivet pitch

shall be gradually increased for a length equal to one and one-half times the maximum width of the member until the maximum spacing is reached. In angles having two lines of staggered rivets in one leg, the pitch on each line may be twice that specified above, but not greater than that allowed for the body of the member.

14. Edge distance of rivets. The minimum distance from the center of any rivet to a sheared edge shall be:

For $\frac{7}{8}$-inch rivets, $1\frac{1}{2}$ inches.
For $\frac{3}{4}$-inch rivets, $1\frac{1}{4}$ inches.
For $\frac{5}{8}$-inch rivets, $1\frac{1}{8}$ inches.

The minimum distance from rolled or planed edges, except flanges of beams and channels, shall be:

For $\frac{7}{8}$-inch rivets, $1\frac{1}{4}$ inches.
For $\frac{7}{8}$-inch rivets, $1\frac{1}{8}$ inches.
For $\frac{5}{8}$-inch rivets, 1 inch.

The maximum distance from any edge shall be eight times the thickness of the thinnest outside plate, but shall not exceed 5 inches.

15. Long rivets. Long rivets subject to calculated stress and having a grip in excess of four and one-half diameters shall be increased in number at least 1 per cent for each additional $\frac{1}{16}$ inch of grip. If the grip exceeds six times the diameter of the rivet, specially designed rivets shall be used.

16. Rivets in tension. Rivets in direct tension shall, in general, not be used. However, where so used their value shall be one-half that permitted for rivets in shear. Countersunk rivets shall not be used in tension.

17. Depth ratios. Trusses preferably shall have a depth not less than one-tenth of the span, plate girders a depth not less than one-twelfth of the span, and rolled beams a depth not less than one-twentieth of the span. If less depths than these are used, the sections shall be increased so that the maximum deflection will not be greater than if these limiting ratios had not been exceeded.

18. Parts accessible. The accessibility of all parts of a structure for inspection, cleaning and painting shall be insured by the proper proportioning of members and the design of their details.

19. Open sections and pockets. Closed sections shall, in general, be avoided.

Pockets or depressions which will retain water shall be avoided as far as possible and those which are unavoidable shall be provided with effective drain holes or shall be effectively filled with waterproof material.

Details shall be arranged so that the retention of dirt, leaves, or other foreign matter will be reduced to a minimum. Wherever angles are used, either singly or in pairs, they preferably shall be placed with the vertical legs extending downward.

20. Symmetrical sections. Main members shall be proportioned so that their neutral axes shall be as nearly as practicable in the center of the section.

In general, the gravity axes of main truss and other important members, meeting to form a joint, shall intersect in a common point so as to avoid eccentricity of stress.

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ERRATA SHEET

Bulletin No. 1259 U. S. Department of Agriculture.

Page 30, beginning with line 12 should read as follows:

The minimum distance from rolled or planed edges, except flanges of beams and channels, shall be:

For 7/8-inch rivets, 1-1/4 inches.
For 3/4-inch rivets, 1-1/8 inches.
For 5/8-inch rivets, 1-inch.

In cases of unavoidable eccentricity the members affected thereby shall be proportioned and the connection details designed to resist the stresses produced.

21. Effective area of angles in tension.

The effective area of single angles in tension shall be assumed as the net area of the connected leg plus 50 per cent of the area of the unconnected leg.

The effective area of a double-angle tension member shall be assumed as 80 per cent of the net area of the member unless the end details and connections are such that the individual angles are held against bending in both directions, in which case the full net area may be used. When the angles connect to separate gusset plates, as in the case of a double-webbed truss, the gusset plates shall be stiffened by diaphragms in the line of the connected angles or by tie-plates extending to the ends of the angles if they are to be considered as offering such resistance to bending that the full net area can be used. When the angles are connected back to back on opposite sides of a single gusset plate the support may be assumed to be sufficient to allow the use of the full net section.

Lug angles shall not be considered as effective in transmitting stress.

22. Strength of connections.

Unless otherwise provided all connections shall be proportioned to develop not less than the full strength of the members connected.

No connection, except for lacing bars and handrails, shall contain less than three rivets.

23. Splices.

Continuous compression members in riveted structures, such as chords and trestle posts, shall have milled ends and full contact bearing at the splices.

All splices, whether in tension or compression, shall be proportioned to develop the full strength of the members spliced and no allowance shall be made for milled ends of compression members.

Splices shall be located as close to panel points as possible and, in general, shall be on that side of the panel point which is subjected to the smaller stress.

The arrangement of the plates, angles, or other splice elements shall be such as to make proper provision for the stresses in the component parts of the members spliced.

24. Indirect splices.

In all splice plates not in direct contact with the parts they connect, the number of rivets on each side of the joint shall be in excess of the number which would otherwise be required for a contact splice to the extent of two extra transverse lines for each intervening plate.

25. Fillers.

Where indirect splices involve rivets carrying stress and passing through fillers, the fillers shall be extended beyond the splicing material and the extension secured by additional rivets sufficient in number to develop the section of the filler.

When the filler is less than $\frac{1}{4}$ inch thick the splicing material shall also be extended.

26. Gusset plates. Gusset or connecting plates shall be used for connecting all main members, except in pin-connected structures. In proportioning and detailing these plates the rivets connecting each member shall be located, as nearly as practicable, symmetrically with the axis of the member. However, the full development of the elements of the member shall be given due consideration. The gusset plates shall be of ample thickness to resist shear, direct stress, and flexure acting on the weakest or critical section of maximum stress.

Reentrant cuts shall be avoided as far as possible.

27. Minimum thickness of metal. The minimum thickness of structural steel shall be $\frac{5}{16}$ inch except for fillers and railings. However, gusset plates shall not be less than $\frac{3}{8}$ inch in thickness.

Metal subjected to marked corrosive influence shall be increased in thickness.

Cast steel shall not be less than 1 inch and cast iron not less than $1\frac{1}{4}$ inches thick, except for filler blocks.

28. Compression members. In built compression members the metal shall be concentrated as much as possible in the webs and flanges, so that the center of gravity of the section may be as near the center line of the member as practicable.

29. Plates in compression. Cover plates of built compression members and cover plates on the compression flanges of plate girders shall have a minimum thickness of one-fortieth, and the web plates of compression members a minimum thickness of one-thirtieth of the transverse distance between the lines of rivets connecting them to the flanges. However, failing to meet this requirement, the width of plate between the connecting lines of rivets in excess of 40 times the thickness of cover plates and 30 times the thickness for web plates shall not be considered as effective in resisting stress.

30. Outstanding flanges. Outstanding compression flanges of girders and main compression members shall have a minimum thickness of one-twelfth of the width of the outstanding flange. For lateral bracing and other secondary members this minimum thickness may be one-fourteenth of the width of the outstanding flange.

31. Tie-plates. The open sides of compression members shall be provided with lacing bars and shall have tie-plates as near each end as practicable and at intermediate points where the lacing is interrupted. Compression members composed of two angles and a cover plate shall have, on their open sides, ties composed of short lengths of channel section with the flanges riveted to the vertical legs of the angles.

Tension members composed of shapes shall have their separate segments connected by tie-plates or by tie-plates and lacing bars.

The thickness of the tie-plates shall be not less than one-fiftieth of the distance between the connecting lines of rivets. Tie-plates shall be connected by not less than three rivets on each side and in members having lacing

bars the last rivet in the tie-plate shall preferably also pass through the end of the adjacent bar.

For main compression members the end tie-plates shall have a length not less than 1½ times the perpendicular distance between the lines of rivets connecting them to the member and the intermediate tie-plates a length not less than that distance. For main tension members the end tie-plates shall have the length above specified for end tie-plates on main compression members and the length of the intermediate tie-plates shall be not less than three-fourths the length specified for intermediate tie-plates on compression members. In tension members whose elements are connected by tie-plates only, the distance center to center of plates shall not exceed 3 feet.

For lateral struts and other secondary members the length of end and intermediate tie-plates shall be not less than three-fourths the perpendicular distance between the lines of rivets connecting them to the member.

32. Lacing bars

The lacing of compression members shall be proportioned to resist a transverse shear not less than that calculated by the formula:

$$S = 300\ A.$$

where

S = transverse shear in pounds.
A = gross area of member in square inches.

This shear shall be considered as divided equally among all stiffening parts in parallel planes, whether made up of continuous plates or of lattice. The stress in the individual lacing bar shall be taken as the component of the the shear, in the direction of the bar, in case single lacing is used and half that amount if double lacing is used. The size of the bar shall be determined by the column formula in which "L" shall be taken as the distance between the connections to the main sections.

The minimum width of lacing bars shall be:

For ⅞-inch rivets, 2½ inches.
For ¾-inch rivets, 2¼ inches.
For ⅝-inch rivets, 2 inches.

Lacing bars having two rivets in each end shall be used for flanges 5 inches or more in width.

The minimum thickness of bars shall be one-fortieth of the distance between end rivets in the case of single lacing and one-sixtieth of this distance for double lacing.

Double lacing, riveted at the intersections, shall be used when the perpendicular distance between rivet lines exceeds 15 inches.

The inclination of single lacing shall generally be about 60 degrees, and for double lacing it shall be about 45 degrees to the axis of the member. Furthermore, the maximum spacing of lacing bars shall be such that the ratio of length to radius of gyration $\left(\frac{L}{r}\right)$ for the portion of

single flange between consecutive connections will be smaller than this ratio for the member as a whole.

Shapes of equivalent strength may be used instead of flats.

33. Net section at pins. Pin-connected riveted tension members shall have a net section, both through the pinhole and back of the pinhole, at least 25 per cent in excess of the net section of the body of the member.

34. Net section of riveted tension members. In calculating the required area of riveted tension members, net sections shall be used in all cases, and in deducting rivet holes they shall be taken as $\frac{1}{8}$ inch larger than the nominal diameter of the rivet.

The net section shall be the least area which can be obtained by deducting from the gross sectional area the area of holes cut by any straight or zigzag section across the member, counting the full area of the first hole and a fractional part of each succeeding hole, the fractional part being determined by the formula:

$$X = 1 - \frac{S^2}{4gh}$$

where X = fraction of rivet hole to be deducted.

S = stagger or longitudinal spacing of rivet with respect to rivet on last gauge line.

g = distance between gauge lines, or transverse spacing.

h = diameter of rivet holes, or nominal diameter of rivet plus $\frac{1}{8}$ inch.

35. Location of pins. Pins shall be located, with respect to the neutral axes of the members, so as to reduce to a minimum secondary stresses due to bending.

36. Pin plates. Pin plates shall be of sufficient thickness to provide the required bearing area upon the pin; they shall be as wide as the dimensions of the member will allow, and their length, measured from pin center to end, shall be at least equal to their width. Pin plates shall contain sufficient rivets to distribute their due proportion of the pin pressure to the full cross section of the members; only the rivets located within two lines drawn from the pin center toward the body of the member and inclined at 45 degrees to the axis of the member shall be considered effective for this purpose. In the case of members composed of web plates and flange angles (with or without a cover plate) there shall be at least one outside pin plate covering the vertical legs of the flange angles.

At the ends of compression members at least one pair of pin plates shall extend not less than 6 inches beyond the near edge of the tie plate.

All pin-connected compression members shall be provided with hinge plates having a minimum thickness of $\frac{3}{8}$ inch.

37. Forked ends. Forked ends on compression members will be permitted only when unavoidable. When used a sufficient number

of pin plates shall be provided to give each jaw the full strength of the compression member. At least one pair of these plates shall extend to the far edge of the tie-plates, and the others not less than 6 inches beyond the near edge of the tie-plates.

38. Pins and pin nuts.

Pins shall be proportioned for the maximum shears and bending moments produced by the stresses in the members connected. If there are eyebars among the parts connected, the diameter of the pin shall be not less than two-thirds of the width of the widest bar attached.

Pins shall be of sufficient length to secure a full bearing of all parts connected upon the turned body of the pin. They shall be secured in position by hexagonal chambered nuts or by hexagonal solid nuts with washers. Where the pins are bored, through rods with cap washers may be used. In general, malleable castings conforming to the requirements of Section 7, Division I, shall be used for pin nuts. Pin nuts shall be secured by cotters in the screw ends.

39. Bolts.

Unless specifically authorized, bolted connections will not be permitted. Bolts, when used, shall be unfinished or turned as specified and shall meet the requirements of Article 19, Section 1, Division II.

Bolts in tension shall have double nuts.

40. Upset ends.

Bars and rods with screw ends shall be upset to provide a cross-sectional area at the root of the thread which shall exceed the net section of the body of the member by at least 15 per cent.

41. Sleeve nuts.

Sleeve nuts shall not be used.

42. Expansion.

Provision for expansion and contraction to the extent of $\frac{1}{8}$ inch for each 10 feet of span shall be made for all bridges. Expansion ends shall be firmly secured against lifting or lateral movement.

43. Expansion bearings.

Spans of less than 70 feet may be arranged to slide upon metal plates with smooth surfaces. Spans of 70 feet and over shall be provided with rollers or rockers, or with the special sliding bearings described below. Neither rollers nor rockers shall be used for expansion bearings at the top of trestle posts.

44. Fixed bearings.

Fixed bearings shall be firmly anchored.

45. Hinged or pin bearings.

Spans of 70 feet and over shall have hinged or pin bearings at both ends. The pedestals or shoes shall be so designed that all loads will act through the end pins, which will be located directly over the geometrical center of the bearing.

46. Rollers.

Expansion rollers shall be not less than 4 inches in diameter for span lengths of 100 feet or less, and this minimum shall be increased not less than 1 inch for each additional 100 feet of span and proportionately for intermediate lengths. They shall be connected by substantial side bars and shall be effectually guided so as to prevent lateral movement, skewing, or creeping. The rollers and bearing plates shall be protected from dirt and water as far as possible, and the construction shall be such

that water will not be retained and that the roller nests may be inspected and cleaned with the minimum difficulty.

47. Rockers. Pin-bearing expansion rockers shall be of cast steel or cast iron.

48. Special sliding expansion bearings. Sliding plates for the expansion bearings of spans of 70 feet and over shall be of Class A bronze, conforming to the requirements of Section 8, Division I. These plates shall be chamfered at the ends and shall be held securely in position, usually by being inset into the metal of the pedestals and sole plates. Provision shall be made against any accumulation of dirt which will obstruct their free movement.

49. Pedestals and shoes. Pedestals and shoes shall be designed to secure rigidity and stability and to distribute the reaction uniformly over the entire bearing area. Preferably, they shall be made of cast steel or structural steel. The bottom bearing widths shall not exceed the top bearing widths by more than twice the depth of pedestal, and, when involving pin bearings, this depth shall be measured from the center of pin.

Where built pedestals and shoes are used, the web plates and the angles connecting them to the base plates shall be not less than ½ inch thick. If the size of the pedestal permits, the webs shall be rigidly connected transversely.

50. Inclined bearings. For spans on an inclined grade and without pin or hinged bearings, the sole plate shall be beveled so that the substructure bridge seats will be level.

51. Anchor bolts. Trusses, girders, and I-beam spans shall be securely anchored to their substructures. Anchor bolts shall be roughened by being screw-threaded or swedged to secure a satisfactory grip upon the material used to embed them in the holes.

The following are the minimum requirements for each bearing:

For I-beam spans the outer beams shall be anchored at each end with two bolts 1 inch in diameter, set 10 inches in the masonry.

For girder and truss spans—

50 feet in length or less, 2 bolts, 1-inch diameter, set 10 inches in masonry.

51 to 100 feet in length, 2 bolts, 1¼-inch diameter, set 12 inches in masonry.

101 to 150 feet in length, 2 bolts, 1½-inch diameter, set 15 inches in masonry.

151 feet and over, 4 bolts 1½-inch diameter, set 18 inches in masonry.

Anchor bolts subject to tension, as in the column bases of trestle bents and towers, shall be designed to engage a mass of masonry which will secure a resistance equal to one and one-half times the calculated uplift.

FLOOR SYSTEM.

52. Floor beams.

Floor beams preferably shall be at right angles to the trusses or main girders and shall be rigidly connected thereto. In general, floor-beam connections shall be located above the bottom chord and in riveted work the bottom chord lateral system shall engage both the bottom chord and the floor beam. Floor-beam connections to pin-connected trusses preferably shall be above the bottom-chord pins, but, if located below, the vertical posts shall be extended below the pins to secure rigid connections to the floor beams.

53. End floor beams.

Except in skew bridges end floor beams shall be provided on all truss and girder spans. End floor beams preferably shall be designed to permit the use of jacks for the future lifting of the superstructure, under which condition the specified unit stresses shall not be exceeded by more than 50 per cent.

End floor beams shall be arranged to permit future painting of the sides of the beams adjacent to the abutment back walls.

54. Stringers.

Steel stringers preferably shall be riveted between the floor beams, with end connections to the floor beam webs.

55. End struts.

When end floor beams are not used the end panel stringers shall be secured in correct locations by end struts securely connected to the stringers and to the main trusses or girders. The end panel lateral bracing shall be rigidly attached to the main trusses or girders and shall also be attached to the end struts. Adequate provision shall be made for the expansion movement of stringers.

56. End connections for floor beams and stringers.

The end connection angles of floor beams and stringers shall not be less than $\frac{3}{8}$ inch in thickness. When milled ends are required, the thickness of connection angles shall be $\frac{1}{16}$ inch greater than for connection angles not required to be milled. Except in cases of special end floor beam details, end connections for floor beams and stringers shall be made with two angles at each end. Bracket or shelf angles which may be used to furnish support during erection shall not be considered in determining the number of rivets required to transmit end shears.

End connection angles shall develop the full depth of the webs by having a length as great as the flanges will permit.

In the preparation of end connection details special care shall be exercised to provide ample clearance for the driving of field connection rivets.

The use of any kind of floor-beam hanger which does not prevent all rotation or longitudinal motion of the floor beam, will not be permitted.

57. Expansion joints. To provide for expansion and contraction movement, suitable floor expansion joints shall be provided at the expansion ends of all spans and at other points where they may be required.

Apron plates, when used, shall be designed to properly bridge the joint and to prevent, as far as possible, the deposit of roadway débris upon the bridge seats.

BRACING.

58. Design of bracing. Lateral, longitudinal, and transverse bracing shall be composed of angles or other shapes offering resistance to deformation when subjected to compressive stress, and shall have riveted connections.

In general, bracing shall consist of a double system of diagonal tension members with transverse compression members. The diagonals in each system shall be proportioned to carry the total lateral stress in tension, the transverse struts (or floor beams) acting as compression members for both systems.

All intersections of lateral and sway bracing shall be riveted to add rigidity and prevent deformations.

59. Lateral bracing. Bottom lateral bracing shall be provided in all bridges except I-beam spans, from which it may be omitted. Bottom laterals preferably shall be supported by rigid hangers at the intersections.

Top lateral bracing shall be provided in deck spans and in through spans having sufficient head room.

Lateral bracing for compression chords shall preferably consist of either two-angle or four-angle latticed sections; and so designed as to engage effectively both flanges of the chords.

Lateral bracing shall have concentric connections to chords at end joints, and preferably throughout. The connections between the lateral bracing and the chords shall be designed to avoid, as far as possible, any bending stress in the truss members.

60. Portal and sway bracing. Through truss spans shall have portal bracing, preferably of the two plane or box type, rigidly connected to the end post and top-chord flanges, and constructed as deep as the minimum clearance will allow. When a single plane portal is used it preferably shall be located in the central transverse plane of the end posts, with diaphragms between the webs of the posts to provide for a proper distribution of the portal stresses. The portal bracing shall be designed to take the full end reaction of the top chord lateral system and the end posts shall be designed to transfer this reaction to the truss bearings.

Deck truss spans shall have adequate sway bracing at the ends and at all intermediate panel points. This bracing shall occupy the full depth of the trusses below the floor system. The bracing shall be proportioned to transfer the end reaction of the top lateral system to the substructure.

Through truss spans shall have sway bracing at each intermediate panel point if the height of the trusses is such as to permit a depth of 5 feet or more for the bracing. When the height of the trusses will not permit of such depth the top lateral struts shall be provided with knee braces. Top lateral struts shall be at least as deep as the top chord. Sway bracing shall be of ample strength to transfer one-half of the wind pressure to the leeward truss.

61. Cross frames.

Deck plate-girder spans shall be provided with cross frames at each end proportioned to resist all lateral forces, and shall have intermediate cross frames at intervals not exceeding 15 feet. These frames shall be connected to the outstanding legs of the stiffener angles and to the girder flanges.

62. Low truss spans.

The vertical truss members and the floor beam connections of low truss spans shall be proportioned to resist a lateral force, applied at the top chord panel points of the truss, determined by the following equation:

$$R = 150\ (A + P)$$

where

R = lateral force in pounds.
A = area of cross section of chord in square inches.
P = panel length in feet.

This rigidity may be secured in part by extending one or both of the floor beam connection angles upward along the inside of the post. Preferably outrigger brackets attached to the vertical posts on the outside of the trusses shall not be used.

63. Through girder spans.

Through plate-girder spans shall be stiffened against lateral deformations by means of gusset plates or knee braces with solid webs, attached to the stiffener angles and floor beams. If the unsupported length of the inclined edge of the gusset plate exceeds 60 times its thickness, the gusset plate shall have stiffener angles riveted along its edge.

These braces generally shall extend to the clearance line and preferably shall be spaced not farther apart than 15 feet.

64. Railings.

Substantial railings shall be provided along each side of the bridge for the protection of traffic. In general the railings shall be of two classes, viz:

1. Railings suitable for use on country bridges which are not subject to general pedestrian traffic.
2. Railings for the protection of pedestrians on bridges in cities or villages.

The top rail of all railings shall be located approximately 3 feet 6 inches above the bridge floor and shall be capable of resisting a horizontal force of 100 pounds per linear foot.

Railings of the first class may consist of not less than two lines of horizontal rails of approved section.

Railings of the second class shall consist of an upper and lower horizontal rail connected by a suitable web. The clear distance between the floor and the lower rail shall not exceed 6 inches.

Preferably the unsupported length of any rail section shall not exceed 8 feet, and all connections to posts, truss members, etc., shall contain not less than two rivets each. Ample provision shall be made for movement due to temperature.

PLATE GIRDERS.

65. Proportioning. Plate girders shall be proportioned either by assuming the flanges to be concentrated at their centers of gravity or by the moment of inertia of the net section. In the former case one-eighth of the gross area of the web is available as net flange area but the effective depth shall not be assumed to be greater than the distance back-to-back of flange angles. For girders having unusual cross sections the moment-of-inertia method shall be used.

66. Flange sections. The gross section of the compression flange shall not be less than the gross section of the tension flange. The compression flange preferably shall be stayed against lateral deflection at intervals not exceeding 12 times its width.

The flange angles shall form as large a portion of the gross area of the flange as practicable.

When flange plates are used, at least one plate on the top flange shall extend the full length of the girder. Any additional flange plates shall be of such length as to allow two rows of rivets to be placed at each end of the plate beyond its theoretical end, and there shall be a sufficient number of rivets at the ends of each plate to develop its full stress value before the theoretical end of the next outside plate is reached.

Flange cover plates shall be equal in thickness, or shall diminish in thickness from the flange angles outward. No plate shall have a thickness greater than that of the flange angles.

67. Web plates. Web plates shall be proportioned for both the vertical and horizontal shearing stresses. Splices in web plates shall be avoided as far as possible, but, when used, they shall be designed to develop the full value of the web plate for both bending and shearing stresses.

68. Flange rivets. The number of rivets connecting the flange angles to the web plates shall be sufficient to develop the increment of flange stress transmitted to the flange angles, combined with any load that is applied directly to the flange. For electric railways, one wheel load, when applied directly to the flange, shall be assumed to be distributed uniformly over a length of 3 feet.

69. Flange splices.

Splices in flange members shall not be used except by special permission of the engineer. Two members shall not be spliced at the same cross section and, if practicable, splices shall be located at points where there is an excess of section. The net section of the splice shall exceed by 10 per cent the net section of the member spliced. Flange angle splices shall consist of two angles, one on each side. Splice angles shall be fitted to secure close contact with the material spliced.

70. Web splices.

Web plates shall be symmetrically spliced by plates on each side. The splice shall be equal in strength to the web in both shear and moment. There shall be at least two rows of rivets on each side of the joint.

71. End stiffeners.

Plate girders shall have stiffener angles over end bearings, the outstanding legs of which shall be as wide as the flange angles will allow and shall fit tightly against them. These end stiffeners shall be proportioned for bearing on the outstanding legs of the flange angles, no allowance being made for the legs fitted to the fillets of the flange angles. End stiffeners shall be arranged to transmit the total end reaction and to distribute it over the bearings. They shall not be crimped and the connection to the web shall contain a sufficient number of rivets to transmit the entire reaction.

72. Intermediate stiffeners.

Intermediate stiffener angles shall be riveted in pairs to the web of the girder. The outstanding leg of each angle shall have a width of not more than 16 times its thickness and not less than 2 inches plus one-thirtieth of the depth of the girder.

Intermediate stiffeners shall be spaced at intervals not exceeding:

(a) 6 feet;
(b) The depth of the web;
(c) The distance given by the formula,

$$d = \frac{t}{40}(12{,}000 - S)$$

where d = distance between rivet lines of stiffeners, in inches.
t = thickness of web, in inches.
S = web shear, in pounds per square inch, at the point considered.

When the depth of the web between the flange angles or side plates is less than 60 times the web thickness, intermediate stiffeners may be omitted.

Intermediate stiffener angles shall be placed at points of concentrated loading and shall be designed to transmit the reactions to the girder web. Such stiffeners shall not be crimped.

Other intermediate stiffeners may be crimped.

73. Ends of through girders.

The upper corners of through plate girders, where exposed, shall be neatly rounded to a radius consistent with the size of the flange angles and the vertical height

of the girder above the roadway. The first flange plate or a plate of the same width will be bent around the curve and continued to the bottom of the girder. In a bridge consisting of two or more spans only the corners on the extreme ends need be rounded, unless the spans have girders of varying heights, in which case the higher girders shall have their top flanges neatly curved down at the ends to meet the top corners of the girders in the adjacent spans.

74. End bearings. End bearings of girders on masonry shall be raised above the bridge seat by metal pedestals or plates a height of at least 2 inches.

75. Sole and masonry plates. Sole and masonry plates shall each be not less than ¾ inch thick.

76. Camber. In general, camber will not be required in plate girders except for long spans or special conditions. When used, it shall be sufficient in amount to meet the requirements of the engineer.

TRUSSES.

77. Main features. Preference will be given to trusses with single intersecting web members or other forms of trusses possessing the least ambiguity in computed stresses and the greatest elements of serviceability. Adjustable members in any part of the structure preferably shall be avoided. Members shall be symmetrical about the central planes of trusses and all parts shall be so designed that they can be inspected, cleaned and painted.

Through riveted and pin-connected spans will generally have inclined end posts. Low truss spans shall be of the riveted type. In low truss spans, laterally unsupported hip joints or "flying hips" shall be avoided.

78. Top chords and end posts. Top chords and end posts of low and through truss spans shall be made usually of two side segments with one cover plate and with tie-plates and lacing on the open side. In chords of light section, tie-plates and lacing may be used in place of a cover plate.

Top chords of deck trusses subjected to direct loading shall be designed for the cross bending occasioned by the dead, live and impact loads of the floor system, in addition to the direct chord stresses, and all top-chord splices shall be proportioned for those stresses and any shearing stresses they may receive.

Where the shape of the truss permits, compression chords shall be built continuous, with splices located as near the panel points as possible and preferably on the side subjected to the smaller stress.

The top-chord sections of low truss spans shall be so proportioned that the radius of gyration about the vertical axis of the member shall be at least one and one-half times the radius of gyration about the horizontal axis.

79. Bottom chords. The bottom chords of riveted trusses generally shall be spliced near panel points and on the side farthest away from the center of the span.

Bottom chords composed of angles preferably shall be constructed with the vertical legs of the angles extending downward.

80. Working lines and gravity axes.

For compression members formed of side segments and a cover plate, the working line shall coincide as nearly as practicable with the gravity axis of the section. For symmetrical sections the working line shall coincide with the gravity axis. For two-angle bottom chord or diagonal members the working line may be taken as the gauge line nearest the back of the angle.

81. Camber.

Trusses shall, in general, be given a camber by increasing the length of the top chords an amount in each panel length equal to $\frac{3}{16}$ inch for each 10 feet of their horizontal projection.

82. Rigid members in pin-connected trusses.

Pin-connected trusses shall have stiff riveted members in the first two main panels of the bottom chords at each end of the span, and all web members performing the function of suspenders shall be of stiff riveted construction.

83. Counters and adjustable members.

Rigid counters are perferred. Adjustable counters, when used, shall have open turnbuckles, and in the design of these members an allowance of 10,000 pounds shall be made for initial stress. Only one set of diagonals in any panel shall be adjustable. Sleeve nuts and loop bars shall not be used.

84. Eyebars.

Eyebar heads shall have a cross-sectional area through the center of the pinhole exceeding that of the body of the bar by at least 40 per cent. The net section adjacent to the head shall be not less than that of the main body of the bar. The thickness of the bar shall not be less than $\frac{1}{8}$ of the width and not greater than 2 inches. The form of the head shall be submitted to the engineer for approval before the bars are made. The diameter of the pin shall be not less than two-thirds of the width of the widest bar connected.

85. Packing eyebars.

The eyebars of a set shall be packed symmetrically about the central plane of the truss and as nearly parallel as practicable, but in no case shall the inclination of any bar to the plane of the truss exceed $\frac{1}{16}$ inch per foot. Bars shall be packed as closely as practicable and held against lateral movement, but they shall be arranged so that adjacent bars in the same panel will be separated by at least $\frac{3}{4}$ inch.

All intersecting diagonal bars not far enough apart to clear each other at all times shall be well clamped together at intersections.

Steel filling rings shall be provided, when required, to prevent lateral movements of eyebars or other members connected upon pins.

86. Diaphragms.

Diaphragms shall be provided in the trusses at the end connections of all floor beams. In general, such diaphragms shall extend down to the bottom flange of the floor beam and for at least two rivet spaces above the top flange.

The gusset plates engaging the pedestal pin at the end of a truss shall be rigidly connected by a diaphragm which shall, in general, take direct bearing on the pin. Similarly, the pedestal webs shall, where practicable, be connected by a diaphragm which shall, in general, take bearing on the pin.

A diaphragm shall be provided between gusset plates engaging main members whenever the end tie plate is located at a distance of 4 feet or more from the point of intersection of the members. In general, the web of this diaphragm shall be located in the plane of the latticed flange.

87. Sole and masonry plates. Sole and masonry plates supporting trusses and columns shall each have a thickness of not less than ¾ inch. The bottom chords of trusses shall be raised above the bridge seat at least 2 inches by the use of metal plates or pedestals.

VIADUCTS.

88. Type Viaducts shall consist usually of alternate tower spans and free spans of plate girders or riveted trusses supported on trestle towers. However, in viaducts having a column height less than 35 feet, trestle bents may alternate with the towers.

In viaducts requiring freedom of waterway and in structures having a less total column height than 20 feet, the number of intermediate trestle bents may be increased over that specified above, but, in general, shall not exceed four in number. Ample rigidity shall be secured in the attachment of the superimposed spans to the column caps of the bents.

89. Bents and towers. Each trestle bent shall be composed preferably of two main supporting columns. Towers shall be composed of two bents rigidly braced and strutted both longitudinally and transversely.

90. Single bents. For viaduct spans supported on single bents, the bents, if less than 20 feet in height, shall be pin-connected to their base sections or shall be designed to resist bending.

91. Batter. Columns preferably shall have a transverse batter of not less than 1 horizontal to 12 vertical.

92. Depth of girders. The depths of plate girders in viaducts preferably shall be uniform.

93. Girder connections. Girders of tower spans shall be fastened at each end to the tops of the columns or to the cross girders. Girders between towers shall have one end riveted and shall be provided with an effective expansion joint at the other end. No bracing or sway frame shall be common to abutting spans.

94. Bracing. Towers shall be thoroughly braced, both transversely and longitudinally, with a double system of stiff tension diagonals having riveted connections. Longitudinal and transverse struts shall be placed at caps and bases and at all intermediate panel points. All bracing connections shall be made by gusset plates.

Column splices generally shall be located close to and above the panel points of the bracing.

Horizontal diagonal bracing shall be provided at the tops and bases of towers and at least at all intermediate panel points of the lateral bracing where the tower columns are spliced.

Provision shall be made in column bearings for expansion of the tower bracing. The struts at the base of towers shall be strong enough to slide the movable shoes with the structure unloaded. The coefficient of friction shall be taken at 0.3.

95. Sole and masonry plates.

Sole and masonry plates shall each be not less than ¾ inch thick.

96. Anchorage.

Viaduct bents preferably shall have a sufficient spread at the base to prevent tension in any windward leg. When this is impracticable, the column anchorages shall be designed to resist safely not less than one and one-half times the calculated uplift.

97. Approval of plans.

The construction plans shall consist of shop detail, erection and other working plans showing details, dimensions, sizes of material and other information and data necessary for the complete fabrication and erection of the metal work. Approval of the construction plans shall be secured before fabrication of steelwork is commenced.

The contractor shall furnish the engineer with such blue-print copies of the plans as may be required for approval and construction purposes and upon completion of the work the original plans if required shall be supplied to the engineer. No deviation from the approved plans will be permitted without the written order of the engineer.

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